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RADIOTELEGRAPHY.—*Radio signal fading phenomena.*[1] J. H. DELLINGER and L. E. WHITTEMORE, Bureau of Standards.

INTRODUCTION

In actual communication by radio, many difficulties are encountered that would not be expected by one who is familiar only with the rather precise and clear-cut theory of the subject in books. Some of the phenomena in radio-frequency circuits may be represented accurately by ordinary alternating-current theory, the mathematical treatment being even simplified at radio frequencies. However, the phenomena of transmission of radio waves from one place on the earth's surface to another are of quite a different kind, and involve so many variables that they are very difficult of analysis.

The difficulties which are peculiar to the transmission and reception of the waves in actual radio communication may be divided into: (1) "fading" or "swinging" of the received wave intensity; (2) strays; and (3) interference from other radio stations whose signals it is not desired to receive.

"Fading" is the rapid variation of intensity of the signals received from a given transmitting station, all circuit arrangements at the transmitting and receiving stations remaining constant. It is characteristically a night phenomenon.

"Strays" are electrical disturbances giving rise to irregular interfering noises heard in the telephone receivers of a receiving circuit. They are present in some degree at all times, though they are usually worse at night and in the summer time.

Interference from other stations differs from the other phenomena in that it can be eliminated. The means by which this may be done

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are: (*a*) frequency selection, (*b*) selection of wave direction, and (*c*) guiding the waves along a channel; for example, along a wire. It is interesting to note that the first and last of these means for eliminating interference are also used in sound, while the second, the selection of the direction, cannot be used in sound, since sound waves are longitudinal while the electric waves are transverse. The matter of station interference will not be discussed further in this paper.

In regard to fading and to strays, a considerable literature now exists, much of it being contradictory. The present authors have attempted to coordinate some of the outstanding and fairly well established facts, and to present recent results. Because of the complexity and uncertainty of many of the phenomena, exceptions can be found to almost all generalizations.

Complexity of the problem.—The following four functions are characteristic of radio reception:

Intensity of received signals.
Fading of signals.
Direction of signals.
Strays.

In order to determine the facts regarding these functions, from the analysis of which the causes might be determined, research has to be undertaken to determine their behavior with respect to the following variables:

Frequency of wave,
Kind of wave (as continuous or damped),
Distance,
Place (e. g., sea, sea-shore, plain land, mountainous land, rivers),
Time (e. g., day, night, sunrise, sunset, time of year),
Occurrence of eclipse,
State of solar activity,
Atmospheric electricity,
Terrestrial magnetism,
Miscellaneous (as discontinuities observed in space and in time).

These variables are by no means independent; for instance, the frequency and kind of wave affect differently the phenomena observed at various places and distances. A complete study of the problem would require about 500 separate researches, each of them on a large scale. The completion of some of these researches would cost millions of dollars. The entire mass of data at present available can be considered as completing only a very few of these researches. The known facts about the variation of the four functions with a few of these variables will now be summarized. Following that, a theory will be given interpreting these facts.

EXPERIMENTAL AND OBSERVATIONAL DATA

Intensity of signals in day. (Variation with distance, place, and wave-length.)—The current in a receiving antenna is given by the following expression:

$$I_r \propto \frac{1}{\lambda d} e^{-\alpha \frac{d}{\sqrt{\lambda}}} \qquad (1)$$

where λ is the wave-length, d is the distance from the transmitting station, $e = 2.718....$and α is a constant known as the absorption coefficient. Quantitative measurements by L. W. Austin and others have shown that signals transmitted in the daytime follow this law within about 50 per cent particularly for the longer waves (over 1000 meters). Variations in received current are associated with variations of the absorption coefficient α. It is a minimum for transmission over ocean water and varies greatly over land, apparently depending largely upon the nature of the ground over which the waves travel.

It has been observed that city buildings obstruct short waves. There is some evidence that waves tend to follow water, thus traveling greater distances along the coast than inland, and following rivers very readily. The Alps and other mountains are said by Schwartzhaupt to obstruct signals greatly by day, but little by night.

The intensity of signals received from a given transmitting station varies greatly from day to day. Very long waves, such as those from the Lafayette station in France, vary as much from day to day as they do between day and night. Greater distances are covered by stations of a given power when transmission is along the Mississippi Valley than in other directions in the United States.

For small distances, the factor containing the absorption coefficient in equation (1) is very nearly unity. Within these distances (up to 200 miles in many cases), the intensities of signals during day and during night are about the same, over sea-water at any rate, according to Austin. In transmission entirely in mid-ocean, very little fading has been observed.

The absorption factor of equation (1) also approaches unity as the wave-length is increased. Thus for a given distance long waves are absorbed less than short waves and the falling off in intensity with distance is less marked for long than for short waves.

Intensity and fading of signals at night. (Variation with distance, place, wave-length and kind of wave.)—The average signal intensity is much greater at night than by day, and the fluctuation or fading

is violent at night, these tendencies being more pronounced the shorter the wave-length. Thus abnormally great distances are obtained at night by stations using short waves, even though the power employed is as small as one kilowatt. Signals from such stations in the northeastern part of the United States have been heard across the Atlantic, and off the coast of South America, as well as across the North American continent.

The phenomenon of fading is much better known among amateurs than among commercial radio men because amateurs do most of their radio transmitting and receiving at night and they are limited by law to short wave-lengths. The great fluctuations in the intensity of signals and the extraordinary distances of transmission at night which have been reported by amateurs have not been taken very seriously by professional radio men because there are so many difficulties with radio apparatus that reliable results are hard to get.

What is probably the most comprehensive series ever made of cooperative transmission tests on the phenomenon of fading was conducted during the past year through the cooperation of the American Radio Relay League and the Bureau of Standards. Transmission took place from stations at a number of points in the northwest quarter of the United States according to a prearranged schedule, and simultaneous records of received signal intensity were made by about one hundred specially appointed receiving operators. Through the hearty and enthusiastic cooperation of the officers and members of the American Radio Relay League it has been possible to obtain many thousands of these records and to gain a great deal of information which it would be difficult if not impossible to obtain otherwise without an enormous expenditure. The handling of the records made during these tests as well as many details of the management of the tests have been in the hands of Mr. S. Kruse at the Bureau of Standards. These tests have given an opportunity to confirm in a statistical way what had previously been the impressions received by operators and experimenters in the course of receiving signals for other purposes.

Fading of signals as well as signals of abnormal intensity are obtained only at distances beyond which the absorption has been found to be appreciable. On 200 meter communication, fading is not often found within a distance of 20 miles from the transmitting station, but fading is usually found at a distance of 60 miles or more from the transmitting station.

Three kinds of fading are observed: (1) Fading or swinging having a period of swing of the order of one second or less. This is associated with a given transmitting station. (2) Fading having a period of the order of one minute. This is associated with a region which may be that of either the transmitting or the receiving station. (3) Fading having a period of the order of one hour. This is associated with a general direction of transmission or with a group of transmitting stations.

Signals from a given transmitting station may be received with violent fading by some transmitting stations and simultaneously with very small fading by others. Certain transmitting stations are heard very well by many receiving stations in all directions on some evenings, and heard by very few receiving stations or in only one direction on other evenings. A given receiving station usually "hears" certain transmitting stations with great fading and others with little fading.

Transmission wholly over water (both transmitting and receiving stations far from land) shows little if any fading, while a narrow strip of land intervening introduces fading, according to Nichols. Stations near the coast fade worse than inland stations.

For three successive nights, no short-wave signals were heard in Virginia, though signals 800 meters or longer in wave-length came in with usual intensity. The same phenomenon occurred one night a week later in Baltimore and the District of Columbia. Later on, the ninth radio district (the Middle West) suffered a similar blank. During the District of Columbia anomaly the atmospheric conductivity was very abnormal, changing from a very high to a very low value without a corresponding change in the atmospheric potential gradient. At 12:17 a.m. normal conditions abruptly returned, transmission becoming very good.

Signals on long wave-lengths, up to 23,500 meters, show very little variation in intensity. There is little if any difference in the fading from continuous wave and from spark stations on any wave-length.

Strays. (Variation with place and time.)—Strays are more intense in the summer than in the winter, and in the night than during the day. They are more frequent and more severe in the tropics than in temperate latitudes.

At a given locality most strays come from a given direction. For the northeastern part of the United States this direction is south or south west. Strays are much less common in mid-ocean than near

land, both by day and night. The change from day to night conditions is much more abrupt at sea than on land. Stray storms usually accompany convective weather.

On October 5, 1920, severe strays were observed by receiving stations in New England, and no New England short-wave transmitting stations were heard outside of that locality. Transmission elsewhere was excellent.

Direction of signals. (Variation with time, wave-length, distance and kind of wave.)—Changes in the direction of the wave front of waves reaching a receiving station from a given transmitting station are observed only at long wave-lengths, but are especially marked with continuous waves. They are far more noticeable at night than in the daytime. On 15,000 meters enormous changes in direction are observed at night (as much as 90 degrees within half an hour), while the changes observed during the daytime are very small, seldom exceeding ten degrees. On 1000 meters, direction changes as great as ten degrees are seldom observed.

The readings of direction can seldom be made sharply while changes in direction are occurring. Sometimes when it has been changing very rapidly it becomes impossible to determine on any direction, the direction-finder giving no indication of a minimum signal in any position. The minima observable are less distinct at night than during the day. All direction changes are greater at night than in the daytime.

Direction changes are very small at very short distances from the transmitting station, are great at medium distances, and small again at very great distances from the transmitting station. These facts have been observed particularly regarding signals from the New Brunswick, New Jersey, radio station.

Eckersley states the belief that waves are refracted in passing from sea to land and vice versa. Tests of radio compass stations indicate that those stations which receive signals entirely over water have no error.

Effects of sunrise and sunset. (Intensity, fading, strays, and direction. Variation with wave-length.)—Great variations in the intensity of radio signals of all wave-lengths, even up to 15,000 meters, are observed at sunrise and sunset. Such variations are especially noticeable when transmission is in an east and west direction.

Transmission is not as good between stations when the boundary between dark and daylight intervenes as at other times of the day.

It has been reported that at sunrise and sunset the shorter waves have the advantage over the longer ones in transmission across the Atlantic.

At sunrise or sunset at the sending or receiving stations the intensity of signals on long wave-lengths becomes abnormally great. On short wave-lengths, at sunrise at the receiving stations, the signals from distant stations merely become steadier for a moment before they suddenly become inaudible.

It is possible that the reported differences in the abilities of inland and coastal stations in the United States to receive transatlantic signals may be the result of differences in their relation to the line of sunrise or sunset.

Effects of time of year. (Intensity and strays.)—Signals from distant stations are much louder on winter nights than on summer nights. Signals become poorer in the spring and it is a question whether this is caused by vegetation, ionization, change in temperature, or other factors.

Strays are much less frequent and normally much less intense, in winter than in summer.

Effect of eclipses.—The occurrence of an eclipse has been found to improve signals, even when they pass only through the penumbra.

Effects of atmospheric electricity, terrestrial magnetism, solar activity. (Intensity.)—In contrast to its effect on wire telegraphy, an aurora has very little effect on radio, except possibly short-wave signals. On an auroral evening none of the usual western stations could be heard at Hartford, Connecticut, but that city did succeed in communicating with Boston, a thing which, curiously, is usually impossible. On the day after an aurora a Chicago station copied signals from a station in Los Angeles.

An aurora is preceded by violent variations in the earth's magnetic field, and usually occurs during periods of great sunspot activity. An aurora would seem to be an extreme case of disturbance at or below the Heaviside surface, producing ionization and also strays.

The conductivity of the atmosphere is somewhat greater at night than during the day. The atmospheric conductivity decreases and the potential gradient increases at the ground level at sunrise and sunset.

Culver reports that when the potential gradient and the conductivity of the air fluctuate greatly, strays are intense. He reports also that the intensity of strays varies inversely as the solar constant

and directly as the intensity of the earth's magnetic field.

Over sea the electrical conductivity of the air fluctuates less and is more uniform from day to day than over land.

Discontinuities in space and time. (Intensity and strays.)—It is found that some stations have great difficulty in establishing communication with other stations quite near them though they have no difficulty in reaching other stations much farther away. Stations in the neighborhood of Boston, Massachusetts, furnish examples of this. It has also been found impossible to transmit over 70 miles east from Hartford, Connecticut.

Silent zones, where signals cannot be heard from certain stations, are frequently found at sea, the most noted ones being along the coast or between two bodies of land.

Inland stations have been found to get copy when coastal stations cannot. This may possibly be a sunset phenomenon or the result of the location of the stations with respect to sources of strays.

Stations less than a mile apart may differ radically in the intensity of strays observed and in the intensity of signals received from a given transmitting station.

Meteorological effects. (Intensity, fading, strays.)—A good radio night, that is, one when the signals are loud and the strays are weak, is usually cloudy or is preceded by a cloudy day. Fading, however, is not affected by clouds. Transmission is usually good during and immediately after a rain storm.

While correlations between meteorological and radio conditions have been sought repeatedly, little proof of such correlations has been found.

Indirectly, meteorological conditions such as temperature, convection, etc., at the earth's surface may somewhat affect the regularity of the boundary surface of the Heaviside or aurora layer, and may thus cause night strays and the disappearance of signals. Thus the difference in temperature between land and sea may cause an effect extending far up into the air.

The effect of weather conditions on the insulation of an antenna and the resistance of the ground are principally important in day transmission. The effect of weather conditions on ionization and on the boundaries of the ionized regions in the upper atmosphere are more prominent at night.

During the October, 1920, fading tests conducted by the American Radio Relay League and the Bureau of Standards, it was observed

that fading was small, signals were good, and strays were weak when it was raining at the receiving station. (Cases of little fading, 17; medium fading, 18; severe fading, 9. Signals were weak 4, moderately loud 31, and very loud 7 times. Weak strays 24, medium strays 13, and loud strays 6 times.)

Clouds at the receiving station are conducive to good signals. (Weak signals 9, moderately loud 75, and very loud 17 times.)

It is possible that clouds blanket the upper air from the disturbances of temperature and other effects on the earth's surface.

DISCUSSION AND EXPLANATION

The complexity of the phenomena suggests that the causes are complex, so that no one explanation will fit all the observations. However, many of the more clearly established facts lend themselves very well to the explanation of the transmission of radio waves proposed below.

Daytime transmission.—The waves that travel along the earth's surface (roughly, the sliding waves), and not the waves in the upper atmosphere, are those which are utilized in the daytime. This is indicated by the formula given in equation (1) in which the absorption coefficient, α, varies with the character of the surface over which transmission takes place. It is a minimum for sea water, and is greatly dependent on land characteristics.

For short distances, short waves give the loudest signals, the absorption being negligible. For long distances, during the day time when formula (1) holds true, long-wave signalling is more efficient, for the absorption factor predominates and limits the transmission for short wave lengths.

During the day the waves which get up into the atmosphere can be considered as entirely absorbed by the upper ionized regions, known as the stratosphere. Thus the intensity of the transmitted waves depends on the ground conditions. This is borne out by the fact that day transmission over sea varies very little with time. This is to be expected, because the sea exhibits entire uniformity in its effect on waves passing over it, thus tending to confirm the idea that ground conditions determine wave intensity in the daytime.

The idea that waves are retarded by ionization is a very old one. Elihu Thomson and Fessenden, however, first localized the ionization on the ground, but it has since been assumed to have its seat at higher and higher levels. The ionization of the air, which is not nearly large

enough near the ground to produce any effect, becomes larger as the distance from the earth increases.

The extreme ultraviolet rays of the sun ionize the air, but these rays are entirely absorbed during their penetration of the upper atmosphere. In the daytime, ionization in the higher levels is therefore unquestionably much greater than at lower elevations. Fleming states that the conductivity of the air near the earth's surface is 100,000 times too small to explain the observed absorption of radio waves. The ionization of the upper atmosphere, however, is so very great that it is probable that the waves which penetrate into the higher parts of the air in the daytime are totally absorbed, and that the observed absorption of waves received at a receiving station is to be explained by the losses in the poorly conducting earth itself.

While the variations from day to day in daytime transmission may not be entirely a ground phenomenon, it seems probable that they are attributable to variations in ground conditions.

Intensity and fading of signals at night.—The short radio waves on which signals are heard at great distances during the night must travel detached from the earth's surface, for along the surface these waves are highly absorbed. It is probable that they reach an upper surface of the atmosphere, which is so highly ionized that its electrical conductivity is far greater than that of the surface of the earth, and hence they can travel with relatively little absorption.

The idea of an upper conducting surface between which and the earth's surface electrical waves would be propagated, antedates the use of radio for long-distance communication since it was considered by Fitzgerald in 1893 and by Heaviside in 1900. Considerations largely independent of radio phenomena suggest the following structure and boundaries of the atmosphere, as indicated in figure 1.

(1) The earth's surface, a relatively poor conductor.

(2) The troposphere, about 10 kilometers thick, within which are the causes of our meteorological phenomena, and an atmosphere similar to that which we breathe.

(3) A radioactive layer, separating the troposphere from the region above it. (The existence of this layer is not as well established as the others, nor is its existence so important in explanation of the radio phenomena.)

(4) The stratosphere, or isothermal layer, having a thickness of approximately 100 kilometers. The stratosphere is ionized in the

daytime but quickly loses this property by the recombination of the ions at night.

(5) The Heaviside surface, permanently ionized, and an almost perfect conductor.

The boundaries of these layers are obviously not absolutely horizontal surfaces. The stratosphere is ionized during the day only, the sun's rays being the cause of the ionization. The permanently ionized region above the Heaviside surface is the region of permanent aurora,

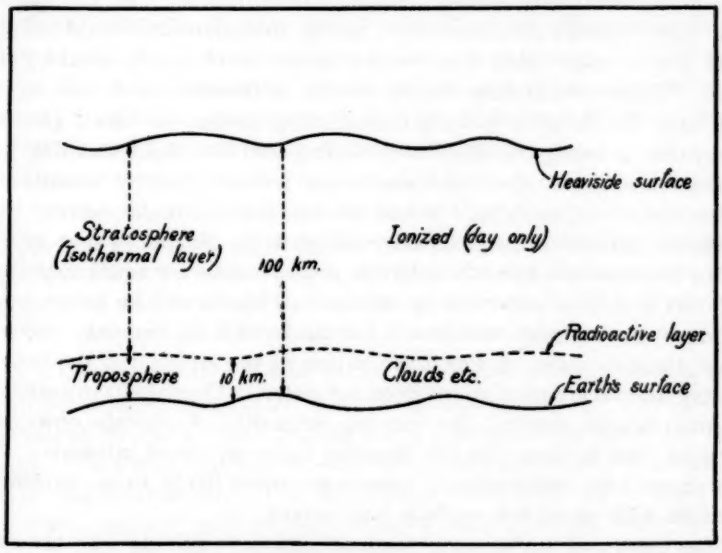

Fig. 1.—Vertical cross-section of the earth's atmosphere.

and is so good a conductor that the waves cannot penetrate it. Any waves reaching it can only slide along it, just as waves slide along the even less perfectly conducting surface of the earth.

Previous explanations of radio transmission phenomena have considered the waves as being constantly reflected back and forth or progressively refracted between the Heaviside surface and the earth, both by day and by night, their intensity being reduced in the daytime by the ionization in the stratosphere. That view does not explain why the waves have the characteristics of ground absorption

in the daytime only, nor why they fade only at night. It seems more nearly correct to consider the daylight transmission of waves as being mainly along the earth as a guiding conductor, none of them being able to reach the Heaviside surface because of the intervening ionized stratosphere, while the waves at night reach the Heaviside surface and travel or slide along it without appreciable absorption.

If this be true, then the waves should reach enormous distances at night, short waves traveling farther than long ones. Because of the variable absorption which may be introduced by the irregularities of the Heaviside surface and the adjoining regions, the waves may vary rapidly in intensity. Small irregularities would affect short waves more than long waves; hence short waves would fade most. These conclusions are in precise agreement with the facts.

Within the distance from a transmitting station in which ground absorption is negligible there is no fading and the night and day intensities are equal, since the waves are not affected by conditions in the upper atmosphere. If the theory given here be correct the maximum intensity of signals received at night should be that given by the transmission formula with the absorption factor equal to unity, and this has been observed to be true. This should be taken as a standard transmission distance. Certainly this is the only unique value, the only value in which the nature of the location of the transmitting and receiving stations does not enter. Thus the transmission formula cannot predict the varying intensity of signals observed at night, but it does give the limiting value of signal intensity. It also shows why extraordinary ranges are more likely to be obtained at night with short waves than long waves.

This theory of night wave transmission is strikingly like the explanation of the flight of the projectile from the German long-range gun. In both cases it is now realized that there exists a region of the upper atmosphere of surprisingly low opposition or resistance.

G. Sagnac says that "zones of weak signals" observed between moving ships are due to the earth's orbital motion dragging the surrounding ether with it. It seems more probable, however, that such phenomena are caused by regions of exceptionally great absorption either of the wave transmitted along the ground or of the wave transmitted along the Heaviside surface, depending upon the conditions.

The relatively small fading on long wave-lengths is partly attributable to the fact that the transmission is along the ground.

If fading were to be explained by reflection and interference between the direct wave and the reflected wave it would seem obvious that fading will be greater in the case of continuous wave stations than spark stations, but apparently this is not the case. It seems probable that the reflection in the upper regions may more truly be considered a quasi-refraction resulting from an increase in the velocity of the waves as they enter the more highly ionized air.

Strays.—Of the several kinds of strays, some have their origin near the receiving station while others are waves sent out by electrical disturbances in certain definite regions such as the western part of the Gulf of Mexico or the central part of Africa. Such regions are mostly tropical. The fact that strays are more intense at night than in the daytime is explained by the greater ease of propagation of all waves at night so that strays which are only local in their effects in the daytime spread to a distance at night.

The strays at night seem to be caused by occurrences at or above the Heaviside surface, because there are times when the strays are intense and yet signals are inaudible or very weak and fading violently. This indicates a turbulent region of ionization over the area involved, which gives rise to strays and which absorbs waves that come into it. The aurora itself represents an extreme case.

Direction of signals.—There is no correlation between fading and direction changes except that both are greater at night. Thus fading is greatest for short waves and direction changes are greatest for long waves. This makes it appear that the explanations of the two may not be closely related. The interference caused by waves from the Heaviside surface may explain the direction changes observed at night (rapid direction changes on long waves), as it is too remote to cause interference with short waves.

Kinsley has suggested that the direction changes may be the result of reflection at the radioactive boundary between the troposphere and the stratosphere.

Effects of sunrise and sunset.—The change from the ionized sunlight condition to the insulating condition of darkness introduces a surface of discontinuity which acts as an obstacle to the waves, partly reflecting them back. It is to be noted that the change takes place in the stratosphere, above the clouds. This deflection of the waves depends on a change in velocity of the waves, produced by the ionization. Since this change in velocity is proportional to the square of

the wave-length, the sunrise and sunset effects are greater for the longer wave-lengths.

Effects of time of year.—The increase of signal strength at night and the scarcity of strays in winter indicate that the Heaviside surface is more nearly level and encumbered with fewer masses of ionized air which are emitting disturbances. This more quiescent condition is probably a result of the sun's acting on the atmosphere for fewer hours each day.

Effects of atmospheric electricity, terrestrial magnetism, solar activity.—There is slight connection between radio phenomena and the usual variations of atmospheric conductivity and similar quantities at the surface of the earth. During intense strays and fading, the conductivity and potential gradient have been known to fluctuate more than usual. This indicates that the masses of ionized air that cause the radio phenomena have a slight effect extending down to the earth's surface.

The visible aurora seems to involve a lowering of the Heaviside surface far down into the stratosphere or even lower. It is known to extend down to about 60 kilometers above the earth's surface. This is done with much turmoil so that it usually stops short-wave radio altogether, or, if signals can be heard, the strays are violent. It completely upsets all usual radio conditions, in fact, in special cases it improves short-wave signal intensity over a certain territory, probably because in this case the lowering of the Heaviside surface envelops the usual source of disturbances.

Discontinuities.—While often difficult to explain, discontinuities are probably caused by some local ionization which acts like a barrier for that particular region. The fact that transmission is good for points beyond the silent zone substantiates the general theory of transmission of waves at night by the upper part of the stratosphere. In such a case they probably go around the barrier.

The origin of this local ionization is unknown. Apparently some local condition on the earth's surface may cause it. It may be direct, as by radioactive emission, or indirect, as by extreme temperature differences or vertical convection currents in the air. Such indirect causes seem probable since there are many cases of discontinuities on or near the coast or in mountainous regions.

The cause of discontinuities is doubtless related to some sort of ionization change such as that accompanying sunrise and sunset.

CONCLUSION

It can be concluded that the causes or sources of fading and of strays are in the atmosphere between the earth's surface and the Heaviside surface. However, the origin of these causes, in turn, is undoubtedly from below the ground or from outside of the earth's atmosphere.

Daytime transmission is effected entirely by means of the waves carried along the ground, while night transmission, especially at great distances and on short waves, is by means of waves transmitted along the Heaviside surface. The latter, at night, are thus free from the absorption to which ground waves are subject in the daytime. They are, however, subject to great variations, caused by irregularities in the Heaviside surface and absorbing masses of more or less ionized air at or near that surface. These variations account for fading.

The theory here given may be only a very rough approximation but it has the advantage of giving a clearer picture than has been available. The inter-relation of radio phenomena and the atmosphere's electrical condition is very close. Subordinate in importance to the atmospheric conductivity are the other electrical properties, the solar constant, and the terrestrial magnetic and meteorological conditions. The properties of the stratosphere seem to be far more important than those of the troposphere, since the stratosphere seems to be the seat of the immediate causes of the observed radio transmission phenomena.

ABSTRACTS

Authors of scientific papers are requested to see that abstracts, preferably prepared and signed by themselves, are forwarded promptly to the editors. The abstracts should conform in length and general style to those appearing in this issue.

GEOLOGY AND HYDROLOGY.—*Ground water in Pahrump, Mesquite, and Ivanpah valleys, Nevada and California.* GERALD A. WARING. U. S. Geol. Survey Water-Supply Paper **450**-C. Pp. 30, pls. 5, figs. 2. 1920.

The report comprises a geographic and geologic sketch and a discussion of the ground waters of the regions named. The valleys consist of detached basins with interior drainage, mountain-rimmed and deeply filled with alluvium. Alluvial fans slope from the mountain areas and grade into the playas which occupy the lowest portions of the basins. Springs occur in all of the valleys, and artesian flows have been obtained in Pahrump Valley. Records of springs and wells are included in the report, and also a brief statement of the quality of the water. The extent of irrigation already practiced, the possibilities of further irrigation development, and the limits of agricultural projects are discussed. N. E. D.

GEOLOGY.—*Geology of Alamosa Creek valley, Socorro County, New Mexico, with special reference to the occurrence of oil and gas.* DEAN E. WINCHESTER. U. S. Geol. Survey Bull. **716**-A. Pp. 15 (1–15), pls. 5. 1920.

This report is based on a field study of the coal resources of the region. Structure is therefore discussed only in a general way and not represented by contours. The geography of the valley lying between the Continental Divide on the west, smaller Tertiary mountain ranges to the south, and the Sierra Ladron on the east, is briefly described. About 8,000 feet of sedimentary rocks from Carboniferous to Recent are exposed. Carboniferous and Triassic represented by red beds are unconformably overlain by Cretaceous consisting of the Dakota sandstone at the base, with a series of shales, sandstones and coal beds overlying it. This upper series is divided into the Miguel formation roughly equivalent to the Mancos shale but more sandy; and the overlying non-marine Chamiso formation containing a Mesaverde flora. Unconformably on the Cretaceous lies the Tertiary Datil formation, largely volcanic with associated sandstones and conglomerates. Quaternary terrace gravels overlie all of these, and all formations except the younger terrace gravels are capped by lava flows. Structurally the area is the southeastern part of the San Juan Basin from the rest of which it is largely separated by the northwest trending Zuni Mountain uplift. The prevailing dip at low angles to the west is interrupted by many faults and minor folds and cut by dikes, most of which trend roughly parallel to the Zuni Mountains. As possible source of oil three larger anticlines are described, the largest 13 miles long. The presence of abundant carbonaceous shales, of coal with about 55 per cent fixed carbon, and of several massive persistent sandstones in the Miguel formation, which can be tested by holes less than 2,000 feet deep, afford favorable indications for the presence of accumulations of oil. The formations older than the Cretaceous may also contain oil accumulations. M. I. GOLDMAN

BOTANY.—*Another conidial Sclerospora of Philippine maize.* WILLIAM H. WESTON, JR. Journ. Agric. Research **20**: 669–684. Pls. 4, figs. 1. 1921.

Another conidial Sclerospora is involved in the destructive maize downy mildew of the Philippines in addition to *Sclerospora philippinensis*, the casual fungus previously described. This second species, found in the Islands of Cebu' Bohol and Leyte, occuring commonly on maize, rarely on the wild grass, *Saccha·um spontaneum*, and once on sugar cane, differs from *S. philippinensis* in that the conidiophores are generally longer and more slender, the basal cells are of much greater length in relation to the main axis, while the conidia especially are longer and less broad; and is described as new under the name of *Sclerospora spontanea*. These specific morphological differences remain constant even through several generations on a range of hosts, including maize, teosinte (*Euchlaena* spp.), *Miscanthus japonicus*, and *Saccharum spontanem*. The size and shape of the conidia, the most valuable criteria of interspecific distinction, are given in detail, measurements of 700 conidia of each being presented in tables and graphs, and the more significant biometric constants being compared. Although morphologically distinct, the two species are alike physiologically in their effect on and in their virulence to the same host species. The probable relationship of the two fungi to the other conidial Sclerosporas of the Orient and to the oogonial stages of the Philippines is discussed. The occurrence of

Sclerospora spontanea on the wild *Saccharum spontaneume* is regarded as evidence that the disease has passed and is passing from this native host to introduced maize. W. H. W.

ENTOMOLOGY.—*The North American ichneumon-flies of the tribes Lycorini, Polysphinctini, and Theroniini.* R. A. CUSHMAN. Proc. U. S. Nat. Mus. **58:** 7–48. Pl. 2. 1920.

This paper adds another to the series of papers revising the American tribes of the subfamily *Ichneumoninae* (*Pimplinae*). In it the genera and species are tabulated and described, and notes on the location of the types, biology of the species, and other valuable taxonomic information given in detail. As is usual for papers of this series, the host list and an index of the species treated is included. Several text figures illustrating the structural characters and some drawings and photographs showing the habitus of the insects are added. S. A. ROHWER.

ENTOMOLOGY.—*New Serphidoid, Cynipoid, and Chalcidoid Hymenoptera.* A. A. GIRAULT. Proc. U. S. Nat. Mus. **58:** 177–216. 1920.

This paper contains descriptions of new parasites which have been received for identification by the Bureau of Entomology. Most of the forms characterized are from North America and some few of them are known to be of considerable economic importance. S. A. ROHWER.

ANALYTICAL CHEMISTRY.—*Sulphur in petroleum oils.* C. E. WATERS. Bur. Standards Tech. Paper **177.** Pp. 28, fig. 1. 1920.

Short accounts are given of the theories concerning the origin of the sulphur and sulphur compounds which are found in crude petroleum. The forms of combination in which the element occurs, their identification and significance are briefly discussed. Tests for the detection of sulphur are described, and the copper test is shown to be one of great delicacy. Although it will show the presence of very minute amounts of free sulphur or of hydrogen sulphide, it may be of no value at all when the sulphur is in stable organic compounds. Various methods that have been used for the determination of sulphur in oils, and finally a new procedure, are described. The new method is based on the preliminary treatment of the oil with nitric acid saturated with bromine, followed by fusion with a mixture of sodium nitrate and carbonate.

Data obtained by the analysis of certain oils by this and other methods are given. From these it appears that there is no loss of sulphur by the new method, which is recommended for laboratories which do not have a bomb calorimeter. C. E. W.

ANALYTICAL CHEMISTRY.—*An electrolytic resistance method for determining carbon in steel.* J. R. CAIN and L. C. MAXWELL. Bur. Standards Tech. Paper **141.** Pp. 24, figs. 6. 1919.

Method and apparatus are described for rapidly and accurately determining carbon in steel by absorbing in a solution of barium hydroxide the carbon dioxide resulting from direct combustion of the metal in oxygen, and deducing the carbon content from the change in electrical resistance of the barium hydroxide solution. J. R. C.

PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

BIOLOGICAL SOCIETY

619TH MEETING

The 619th meeting of the Biological Society of Washington was held in the lecture hall of the Cosmos Club at 8.00 p.m., January 22, 1921, with President N. HOLLISTER in the chair, and 112 persons present. Upon recommendation of the Council, Mr. ARTHUR J. POOLE and Mrs. MARION G. BROWN were elected to membership.

Informal communications

Dr. PAUL BARTSCH stated that the Hiraci collection of Japanese and Pacific molluscs had been given to the U. S. National Museum. This with other large collections makes the collection of molluscs in the National Museum the largest in the world. Dr. BARTSCH also stated that a mocking bird was spending a third winter in his yard. It seemed to be the supply of water which is most appreciated.

Dr. R. W. SHUFELDT exhibited a file fish, part of a collection from Argentina, with an apparently abnormal file, it being double.

Dr. T. S. PALMER, referring to the height at which birds fly, stated that W. E. D. SCOTT at Princeton, and Dr. CHAPMAN telescopically observing birds crossing the disk of the sun, estimated their height at 10,000 feet. Photographs of geese crossing the sun's disk yielded an estimate of 29,000 feet or about 5.5 miles. Direct observation from aeroplane has been made up to 10,000 feet.

Dr. H. M. SMITH made the first public announcement of the taking of the large forked-tailed swift, *Microperus pacificus* (Latham), upon the North American Continent. The capture was made by Mr. G. D. HANNA of the Bureau of Fisheries in the Pribiloff Islands.

Mr. A. H. HOWELL stated that the crow roost at Laurel, Maryland, occupied for some ten years, has been abandoned for some other place farther north. Dr. L. O. HOWARD conveyed to the Society the greetings of former President Dr. F. A. LUCAS, who was recently in the city.

Regular program

The speakers were introduced by Dr. J. C. MERRIAM, President of the Carnegie Institution of Washington.

L. H. MILLER, of the University of California: *Asphalt beds of Rancho La Brea.*

The asphalt beds, small and few in number, lie a few miles north of Los Angeles. The asphalt has varied in viscosity from time to time, and has been in a more or less vertical circulation. Since Pleistocene times the beds have served as a constantly baited trap for all kinds of animals, and have gathered a characteristic fauna from that region in great numbers. Referring principally to the birds, Dr. MILLER said that, local as the deposits are, their richness and completeness threw light upon several large biological problems. (1) Questions of phylogeny. The deposits at Rancho La Brea show a very plastic condition of the genus *Haliaetus* in the Pleistocene. Many forms of bald eagles, some larger and some smaller than those now existing,

occurred, and out of this stock the present species seem to have crystallized. (2) Questions of homoplasy. A walking vulture, *Teratornis*, also a walking eagle, occur, both simliar to *Serpentarius*, the secretary bird of Africa, but the former only superficially. (3) Questions of variability. The great variability already referred to exists in other genera also, as in *Bubo* and *Cathartes*. Some forms of these were of tremendous size. Others such as the Californian condor, had reached more stable form. (4) Questions of distribution. Many forms, now Central and South American in distribution, occur at Rancho La Brea. Thus the caracara and the black vulture, rare along the Californian border, are common. *Morphus*, the eagle hawk, and certain storks of Brazil and Argentina, occur in lesser numbers. Here is found *Parapavo*, a peacock-like bird, forming a link, both in distribution and development, between the pheasants of the old world and the ocellated turkey of Yucatan and the turkey of the eastern United States. (5) Indices of climate. Inferences from the present climatic distribution of birds, identical with or similar to those found at Rancho La Brea, indicate a climate more tropical than that of recent times, and supporting a vastly richer assortment of forms. The paper was illustrated with pictures of the asphalt beds and specimens from the beds, and restorations of the life and environment there in Pleistocene days.

H. C. BRYANT, of the University of California: *Birds and mammals of Yosemite Park.*

The speaker called attention to the changing distribution of birds during the day, or season, or with changes in weather. The white-throated swift, apparently on the wing all the daylight hours, feeds on the floor of the valley in the morning, later it flies at middle heights, and in afternoon only about the highest cliffs. As the season progresses many birds spread from the breeding and feeding grounds of the valley to the higher hill region, such as the jay, shrike, and kingbird. On the other hand, storms in the highlands drive birds into the valley, such as the nighthawk. Further notes upon many birds were given. Protection to birds does not l ad in all cases to their increase. This is true of grouse and quail, suggesting unsolved problems. Protection cannot be given to all animals alike. The interrelation between deer and panther is an example.

The speaker emphasized the impossibility of appreciating the fauna and flora of Yosemite or other National Parks or Preserves without familiarity with nature in the field. The interest taken by young and old alike in studies afield of animals and plants justifies a greater development of the naturalist who can interpret the work of the specialist and make it accessible to the nonscientific public. The paper was illustrated by numerous views of Yosemite and of individual birds and animals.

The papers presented by Drs. MILLER and BRYANT were discussed by R. W. SHUFELDT, A. S. HITCHCOCK, DAVID WHITE, and J. C. MERRIAM.

A. A. DOOLITTLE, *Recording Secretary.*

SCIENTIFIC NOTES AND NEWS

The Pick and Hammer Club met at the Interior Department at 8 p.m. on Saturday, April 30. Prof. E. W. BERRY of John Hopkins University gave an illustrated talk on *Impressions of Peru and Bolivia.*

The National Academy of Sciences held its annual meeting in Washington, April 25–27. Sessions for the presentation of scientific papers were held at the National Museum on April 25 and 26. The following-named 15 persons were elected to membership: FRANK MICHLER CHAPMAN, ornithologist, American Museum of Natural History, New York; WILLIAM LEROY EMMET, electrical engineer, General Electric Company; WILLIAM DRAPER HARKINS, chemist, University of Chicago; ALES HRDLICKA, anthropologist, National Museum; ARTHUR WILLIAM KENNELLY, engineer, Harvard University; WILLIAM GEORGE MACCALLUM, pathologist, Johns Hopkins Medical School, Baltimore; DAYTON CLARENCE MILLER, physicist, Case School of Applied Science, Cleveland, Ohio; GEORGE ABRAM MILLER, mathematician, University of Illinois; BENJAMIN LINCOLN ROBINSON, botanist, Harvard University; VESTO MELVIN SLIPHER, astronomer, Lowell Observatory, Flagstaff, Arizona; LEWIS BUCKLEY STILLWELL, electrical engineer, New York City; DONALD DEXTER VAN SLYKE, biochemist, Rockefeller Institute for Medical Research, New York City; THOMAS WAYLAND VAUGHAN, geologist, U. S. Geological Survey; HENRY STEPHENS WASHINGTON, geochemist, Geophysical Laboratory, Carnegie Institution of Washington; ROBERT SESSIONS WOODWORTH, psychologist, Columbia University.

Mr. ARTHUR E. FATH returned to the U. S. Geological Survey on April 29, after several months' furlough.

Dr. JOSEPH GRINNELL, director of the Museum of Vertebrate Zoology, Berkeley, California, was in Washington in May studying the ornithological collections at the National Museum.

Mr. O. B. HOPKINS has submitted his resignation as geologist in the U. S. Geological Survey, effective April 1, to continue his work in the prospective oil fields of Canada.

Dr. ROBERT RIDGWAY, of the U. S . National Museum, received the Daniel Giraud Elliot Medal of the National Academy of Sciences on April 26, for his studies of the birds of North America.

Dr. H. L. SHANTZ, agricultural explorer of the Department of Agriculture, lectured before the Cosmos Club on April 25 on *Some experiences of a trip from the Cape to Cairo.*

Mr. E. W. SHAW, geologist, resigned from the U. S. Geological Survey on March 30 to take up consultation work in oil and gas.

Dr. C. W. STILES, of the Hygienic Laboratory, U. S. Public Health Service, received on April 26 a gold medal of the National Academy of Sciences "for eminence in the application of science to the public welfare," in recognition of his work on the hookworm disease.

Dr. CHARLES D. WALCOTT, Secretary of the Smithsonian Institution, received the first award of the Mary Clark Thompson Medal of the National Academy of Sciences, for distinguished achievement in geology and paleontology. The medal was awarded at the meeting of the Academy on April 26.

Mr. ARTHUR R. WILLIS, chemist with the U. S. Tariff Commission, met death by accidental drowning in the Potomac River on April 24, 1921. Mr. Willis was a native of Ohio, and was 29 years of age. He was a member of the Chemical Society.

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